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A SURVEY OF WESTERN PINE BEETLE DAMAGE

ON THE FREMONT NATIONAL FOREST

USING COLOR PHOTOGRAPHS

by

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INTRODUCTION

The western pine beetle outbreaks in 1962 killed over 25 million board feet of timber on the Fremont National Forest--enough timber to build three times the number of homes in Lakeview, Oregon. It is anticipated that these losses will continue. The annual forest insect survey results show the infestations have increased substantially from 3,800 acres in 1959 to over 99,000 acres in 1962 (Table 1). This serious problem required further evaluation.

Table 1.--Trend of Western Pine Beetle Infestations on the Fremont National Forest, 1955 - 1962

Year	Infestation Centers	Intensity of Infestation: Light	Moderate	Heavy	Very Heavy	Total
	Number	Acres				
1955	4	5,760	0	0	0	5,760
1956	7	2,400	0	0	0	2,400
1957	17	7,040	1,760	0	0	8,800
1958	12	3,360	160	0	0	3,520
1959	7	3,840	0	0	0	3,840
1960	39	18,800	5,040	0	0	23,840
1961	29	13,400	15,520	9,760	2,720	41,400
1962	91	60,790	17,740	12,040	8,440	99,010

THE SURVEY

In the fall of 1962, a survey was made to study past losses and to determine the trend of the outbreak for 1963. From this information, recommendations were to be made to control this forest pest.

The survey used the aerial technique that had been developed in recent years by the Pacific Northwest Forest and Range Experiment Station.[1/] This technique involved the use of ground and photo plots. The first stage of the survey was to establish priority units and take aerial color photographs of these areas (Table 2) (Fig. 1-appendix). Following photography, plots were sampled on the photos and on the ground and the results were analyzed statistically.

1/ Wear, J. F., and P. G. Lauterbach. Color photographs useful in evaluating mortality of Douglas-fir. 1955 Proc. Soc. of Am. Foresters Meeting: 169-171, 1956.

Table 2.--Areas surveyed for western pine beetle infestation Fremont National Forest, 1962

Priority Unit	Ranger District	Area	10 Acre Plots Ground	Photo
		Acres	- - - No.	- - -
Slide Lakes	Paisley	15,360	6	112
Bagley Springs	Paisley	7,040	6	155
North Warner	Lakeview	15,000	6	144
Dog Lake	Drews Valley	7,680	6	126
Thomas Creek	Thomas Creek	3,840	6	103
	Total	48,920	30	640

Objectives

The objectives of this survey were to determine: (1) The volume loss for the past two years, (2) the infestation trend for 1963, (3) the practicability of color photographs for an operational survey, and (4) control recommendations.

Photography

To sample the infested areas, the photographic plan called for flight lines to be flown about 1 mile apart at a height of 8,000 feet above average terrain for a photo scale of 1:8000 (8 inches = 1 mile). The photographs were taken with a 12-inch focal-length camera, using Ektachrome aero color film with a standard overlap of 60 percent. The Station's Cessna 180, modified for aerial photography, was used and the pictures were taken between August 30 and September 7, 1962. The film was processed at the Station's photo laboratory.

The next step was to inscribe photo plots on each stereo-pair. Based on a similar aerial survey that involved another type insect (balsam woolly aphid[2/]), an empirical approach was used to establish the number of photo plots for this survey. A minimum base of 100 photo plots in each of the five critical areas was selected. The variation in the size of each area did not influence the number of plots to be taken in each area. The total number of photo pairs in each area was divided into 100 to indicate the distribution of plots. Fractional plot distributions were increased to full plots on the stereo-pairs. The number of plots inscribed on photo pairs of the different areas ranged from 4 to 10; total photo plots for the five areas were 640 (Table 2).

2/ Pope, R.B., Final Report-Cooperative Evaluation Survey of Chermes Damage Mt. St. Helens, Washington, 1957, U.S. Forest Service Pacific Northwest Forest & Range Experiment Station, 25 pp., August 1958.

Interpretation

After the plots had been inscribed on the color transparencies, the photo interpreter took them into the field. The interpreter, who was also an entomologist, selected trees killed by or infested with western pine beetle to serve as a key for the interpretation of the 640 photo plots. The selection of these "key trees" included as much variation in appearance of attack trees as possible. Special attention was given crown color in relation to the year of attack (1961--red to brown; 1962 spring--yellow to red; 1962 fall--green to slight fading). Each "key tree" was located and circled on the photo with the year of attack indicated. Its diameter was also recorded. Special attention was directed to other insect damaged trees which might be confusing to the interpreter. The majority of these confusing conditions were mountain pine beetle attacks in young ponderosa pine and the fir engraver beetle in true firs. These infested trees appeared reddish-pink on the photographs and were not included in this survey. After selecting and studying the "key trees," the 640 photo plots were interpreted. Each plot was placed into one of three strata according to the number of visibly discolored ponderosa pine trees killed in the past two years:

(1) No visible trees.
(2) 1 or 2 visible trees.
(3) 3 or more visible trees.

These three strata were later used to determine the distribution of field plots for the regression computations, and to determine the proportion of 1961 attacks, 1962 spring attacks, and 1962 fall attacks.

At the time the interpreter detected an infested tree, he would further classify the tree as to the year of attack and into one of the three broad diameter classes based on rough tree height and crown diameter:

(1) 12 to 20 inches d.b.h.
(2) 22 to 32 inches d.b.h.
(3) 34 inches d.b.h. and larger.

A tally form (Fig. 2-appendix) was designed to handle the above information.

An Old Delft Scanning Stereoscope, which has magnifications of 1-1/2 and 4-1/2 power, was used with a light table to view the color transparencies.

Field work

Only a minimum amount of ground work was required for this survey because the double sample straight-line regression technique was used. This technique relies on a small number of ground plots to adjust the large photo sample.

Plot selection--In each of the five units, two plots from each of the three infestation strata (0; 1 or 2; 3 or more trees) were selected for field checking (Table 2), for a total of 30 field plots.

Personnel--The Fremont National Forest furnished eight men, two from four of the five Ranger Districts, to participate in the survey. Three additional men were detailed from other forests (Mt. Hood, Gifford Pinchot, and Wenatchee National Forests). Two- to three-man crews were used for this survey. In the three-man crew, one man kept the crew oriented on the plot while the remaining two men marked the beetle-infested trees. The two-man crew was used only when both men were proficient in reading aerial photographs and recognizing beetle infested trees.

Training--A two-day training session was given to the survey crews emphasizing the use of the color transparencies, recognizing trees infested with the western pine beetle, dating the period of beetle attack, and risk rating ponderosa pine trees.

Since most of the men had never worked with aerial color transparencies, one day was spent training them in interpreting the photos. It was found, when using color transparencies in the field, stereo-interpretation was generally unnecessary. The survey crews were able to locate the plots accurately and kept well oriented on a single transparency. The photographs, backed by a sheet of heavy clear plastic, were held toward the sunlight for viewing. The full range of natural colors on the Aero Ektachrome film and the impression of depth from shadows made orientation for the interpreter relatively easy in the open pine stands. Two portable split-light tables were available for stereo viewing under adverse lighting conditions or in dense stands.

Great care was needed when determining the year of attack. Each man was provided with an identification key (see appendix) to help identify the year of attack. The 1961 beetle killed trees were not separated by summer and winter broods, but the current year attacks (1962) were recorded as to season of attack.

Examples of other types of insect mortality; i.e., top killing, twig dying, other bark beetles, and sapsucker work were pointed out during the training program. Emphasis was placed on the difficulty of recognizing currently infested trees. Training also included risk rating green non-infested trees, using Bongberg's classifications.

The survey ceased whenever heavy clouds or an overcast prevailed because accurate detection and evaluation of tree crowns was not possible.

Technical direction--The Insect and Disease Control Branch of the Division of Timber Management from the Regional Office provided the entomological assistance, while the Pacific Northwest Forest and Range Experiment Station provided aerial photography and the photo interpretation assistance. Both offices helped in checking the field plots to insure accurate collection of data.

Collection of data--The following data were collected for each field plot:

1. Tally, by year of attack, all trees infested with the western pine beetle. Tally by 2-inch diameter class 11 inches and larger. A tally form (Fig. 3-appendix) was designed for the field plots.

2. Using Bongberg's classifications, green non-infested ponderosa pine 11 inches and larger were risk rated (Fig. 3-appendix).

Originally the survey planned to risk rate all non-infested trees on the field plot, but this proved to be too time consuming. The method was changed to risk rating the green non-infested trees on three 1/5-acre plots at 5-chain intervals within the 10-acre ground plot.

Computation

Using the photo and field estimates of the total 1961 and 1962 mortality on the 30 plots, a linear regression was computed (Fig. 4). This was then used to adjust the estimates from the large photo sample in each unit. These adjusted totals were broken down into respective years of attack, using proportions obtained from the field plots. Average proportions for each unit were developed by weighting the field plot proportions by the number of photo plots in each infestation stratum (0, 1-2, 3+ visible infested trees per plot).

SURVEY RESULTS

Trend and Volume

The trend of the western pine beetle infestation on the Fremont National Forest is upward on four of the five units (Table 3). The greatest infestation increase was found on the North Warner Unit where the ratio between 1962 fall attacks and 1962 spring attacks was 6:1. Only one of the five units (Bagley Springs) indicated the infestation to be downward. The total estimated volume loss for the past two years on the five units has been over 25.5 million board feet, of which 9.47 million occurred in 1961 and 16.15 million occurred in 1962.

The information obtained from risk rating the green non-infested ponderosa pine showed that 13 percent of the stand was either high-risk or very high-risk (Table 4). This is about normal for a virgin ponderosa pine stand.

Table 3.--Summary of volume loss caused by the western pine beetle, Fremont National Forest, 1961 and 1962

Unit	Mortality Class 1961 Trees	1961 Volume	1962S Trees	1962S Volume	1962F Trees	1962F Volume	Total Trees	Total Volume	Trend Ratio	Trend Direction
	No.	M bd. ft.	No.	M bd.ft.	No.	M bd.ft.	No.	M bd.ft.		
Slide Lakes	2,594	3,180	885	883	2,656	5,523	6,135	9,586	3.0:1	up
Dog Lake	149	172	299	634	1,626	2,748	2,074	3,554	5.4:1	up
Thomas Creek	550	880	191	306	384	761	1,125	1,947	2.0:1	up
Bagley Springs	1,084	2,025	356	934	134	173	1,574	3,132	.4:1	down
North Warner	2,174	3,215	371	233	2,202	3,952	4,747	7,400	5.9:1	up
Total	6,551	9,472	2,102	2,990	7,002	13,157	15,655	25,619	3.3:1	up

Based on 640 photo plots and 30 ground plots. Plot size 10 acres (5 chains x 20 chains). Data weighted by area and distribution of mortality.

Table 4.--Green stand risk rating distribution on five areas of the Fremont National Forest, 1962

Area	No. of Trees	Low I	Moderate II	High III	Very High IV
		Risk Rating[1/]			
		- - - - - Percent - - - - -			
North Warner	885	42	48	7	3
Bagley Springs	159	45	38	13	4
Slide Lakes	129	35	43	14	8
Thomas Creek	133	38	35	19	8
Dog Lake	78	10	69	15	6
All areas	1,384	40	47	10	3

1/ Based on 45 1/5 acre plots on each area.

Regression sampling and cost comparison

The value of a regression sampling survey is measured by its efficiency--the cost of such a survey relative to a straight field survey of equal precision. The efficiency can be estimated from the correlation coefficient obtained by the photo interpreter and the ratio of field plot cost to photo plot cost. The consistency of the interpreter's ability to evaluate mortality from photographs is shown by his correlation coefficient. A correlation coefficient of 0.78 (1.0 is perfect) was obtained by an interpreter for volumes of beetle killed timber on all five areas. This relationship between photos and field plot volumes (Fig. 4-appendix) was derived from the 30 plots previously mentioned. To establish volume losses, tables were compiled by the Forest from sales data and average volumes were computed for each of three diameter classes (12-20; 22-32; 34+) in each area.

A regression sampling survey made earlier by the Station in Pacific silver fir stands in southern Washington indicated that volume rather than tree numbers provided a better correlation. This theory proved correct in this western pine beetle survey. A reason for this difference in correlation has been the inability of the photo interpreter to detect small diameter trees that are shaded or suppressed. Omission errors of this type adversely affect a correlation coefficient for numbers of trees, but these errors are not generally significant in volume determinations.

Field and photo plot costs are derived from actual costs of the materials, manpower needed, and the proportion applicable to mortality survey. Based on a well-trained three-man crew being able to locate and cruise two separate plots per day, the field costs incurred were $45 per plot. The costs included transportation and other field expenses to and from

a plot. Photo plot costs include all costs of editing and interpreting the photographs, and the computation and analysis of the data. Because additional uses are generally made of the photographs; i.e., sales layout, marking timber, planning roads, and salvaging timber, only one-half of the direct costs of obtaining the photographs was charged to the mortality sampling survey. On this basis, each photo plot (640 total) cost less than $1.50. The ratio of field plot to photo plot costs on this survey is about 30 to 1.

In a regression sampling survey, it is necessary to know the optimum ratio of photo plots to field plots. This can be derived from the graph in Figure 5 in the appendix, which shows the optimum ratio of plots based on correlation coefficients and the plot cost ratio. Based on data from this survey, our actual plot ratio was 21 to 1. However, the optimum plot ratio for this survey should have been 7 to 1. Initially, 75 field plots were planned, but due to field difficulties, this had to be reduced to 30.

For the most efficient regression sampling survey (using 640 photo plots and a 7 to 1 ratio), 92 field plots would have been required. Using the same plot costs ($45 per field and $1.50 per photo), the total double sampling survey would be $5,005. For a ground survey of equal precision, 193 ground plots would have been required at a total cost of $8,680. Under these conditions, the double-sample survey is about 1.75 times more efficient than a straight field survey (Fig. 6-appendix).

Control recommendations

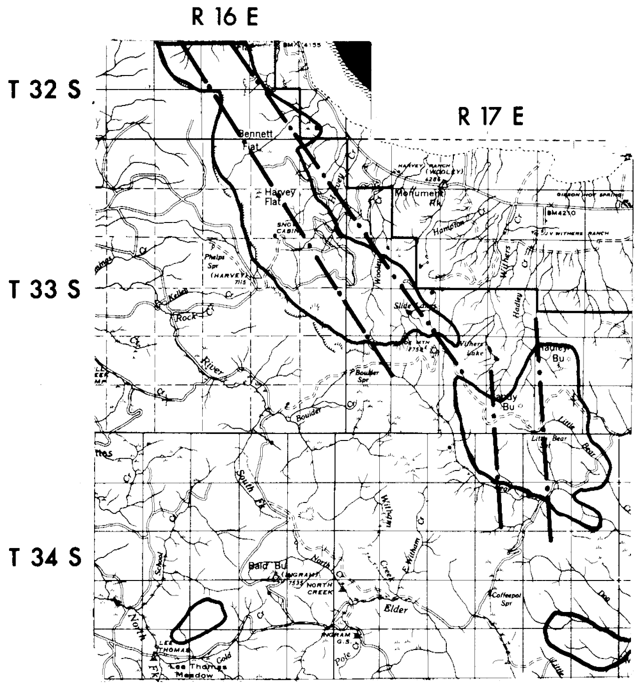
To help reduce the size and intensity of the current western pine beetle outbreak, the following recommendations are made:

1. Remove currently infested trees (those attacked during the fall of 1962) before the beetles emerge in the spring and summer of 1963. Areas in which the heaviest losses have occurred and where the trend of infestation is upward should be given highest priority. These areas are North Warner, Slide Lakes, and Dog Lake. Second priority should be given the scattered remnants of the Thomas Creek infestation since the major portion is planned for sale this year. Lowest priority should be given the Bagley Springs infestation because of the downward trend of losses.

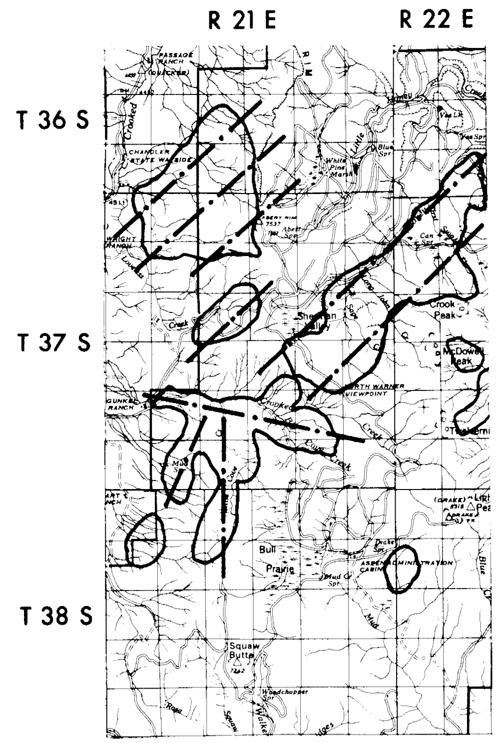
2. Chemical control of the western pine beetle might be necessary in areas not included in currently active or proposed sales. This type of control should be resorted to only as a stop-gap measure.

3. Removal of all "high" and "very high" risk trees in non-infested stands should be carried out with dispatch before this type of tree is attacked by the beetle.

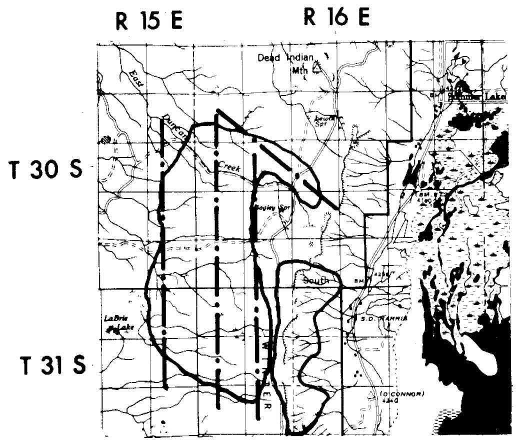
APPENDIX



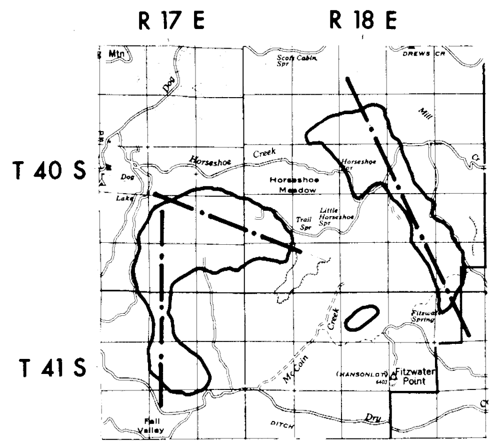
SLIDE LAKES UNIT



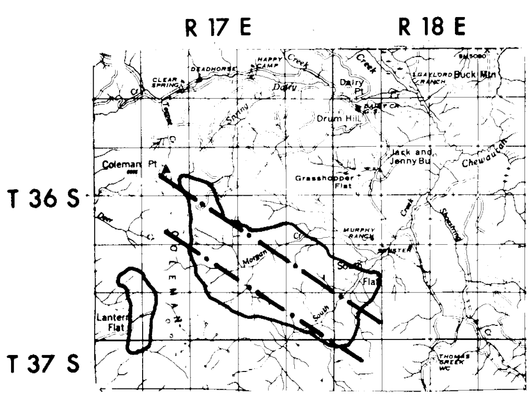
NORTH WARNER UNIT



BAGLEY SPRINGS UNIT



DOG LAKE UNIT



THOMAS CREEK UNIT

Figure 1 -- WESTERN PINE BEETLE INFESTATION Surveyed on FREMONT NATIONAL FOREST 1962

Legend

——— Infestation Boundary - determined by 1962 Annual Aerial Insect Survey

—·— Photo Flight Lines

Scale in miles

0 1 2 3 4 5

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Figure 2 - Photo Interpretation Tally Sheet

Unit - Flight Line Photo & Plot No.	YEAR OF ATTACK						Total Trees
	1961			1962			
	dbh 12 to 20	dbh 22 to 32	dbh 34+	dbh 12 to 20	dbh 22 to 32	dbh 34+	
NW-5-9-5	• • • •	•	•		• • •		9
5-11-1	•						1
5-17-2							0

Figure 3 - Field Plot Tally Sheet

1962 Western Pine Beetle Survey - Fremont

Plot__________ Unit________________ Photo No.________________

Cruiser__________ Date________________ Intensity________________

DBH "			Insect-Killed Ponderosa Pine					Risk		
			Older		1962					
	Pine	Other	Dead	1961	Faded	Green	I	II	III	IV
12"										
14"										
16"										
18"										
20"										
- -	- - -	- - -	- - - - -	- - - -	- - -	- - - - -	- - -	- - -	- - - - -	
- -	- - -	- - -	- - - - -	- - - -	- - -	- - - - -	- - -	- - -	- - - - -	
48"										
50"										
Totals										

Figure 4 **Regression Line for 30 photo and ground plots by volume.**

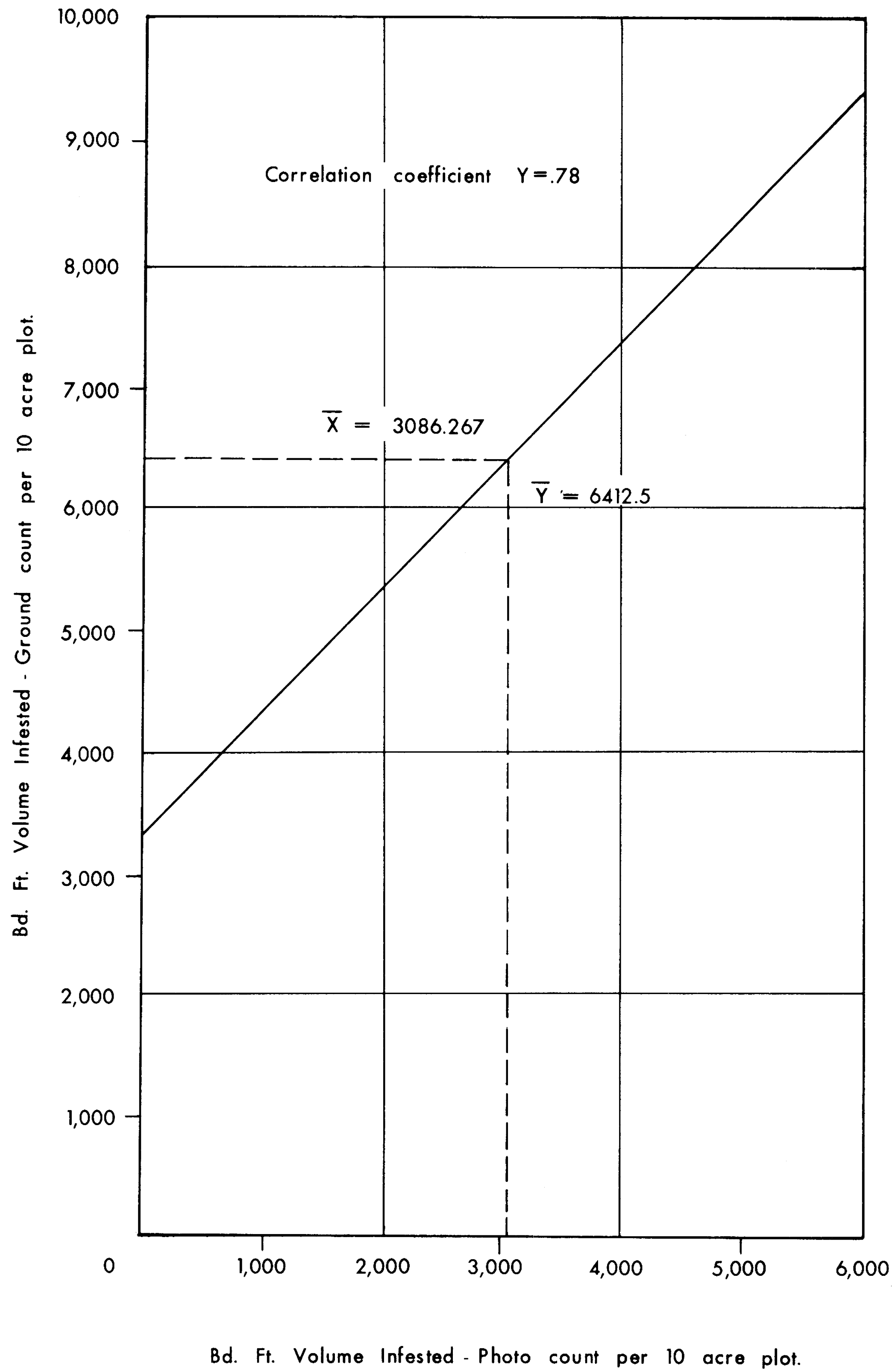


Figure 5

Optimum Ratio of Photo Plots to Field Plots

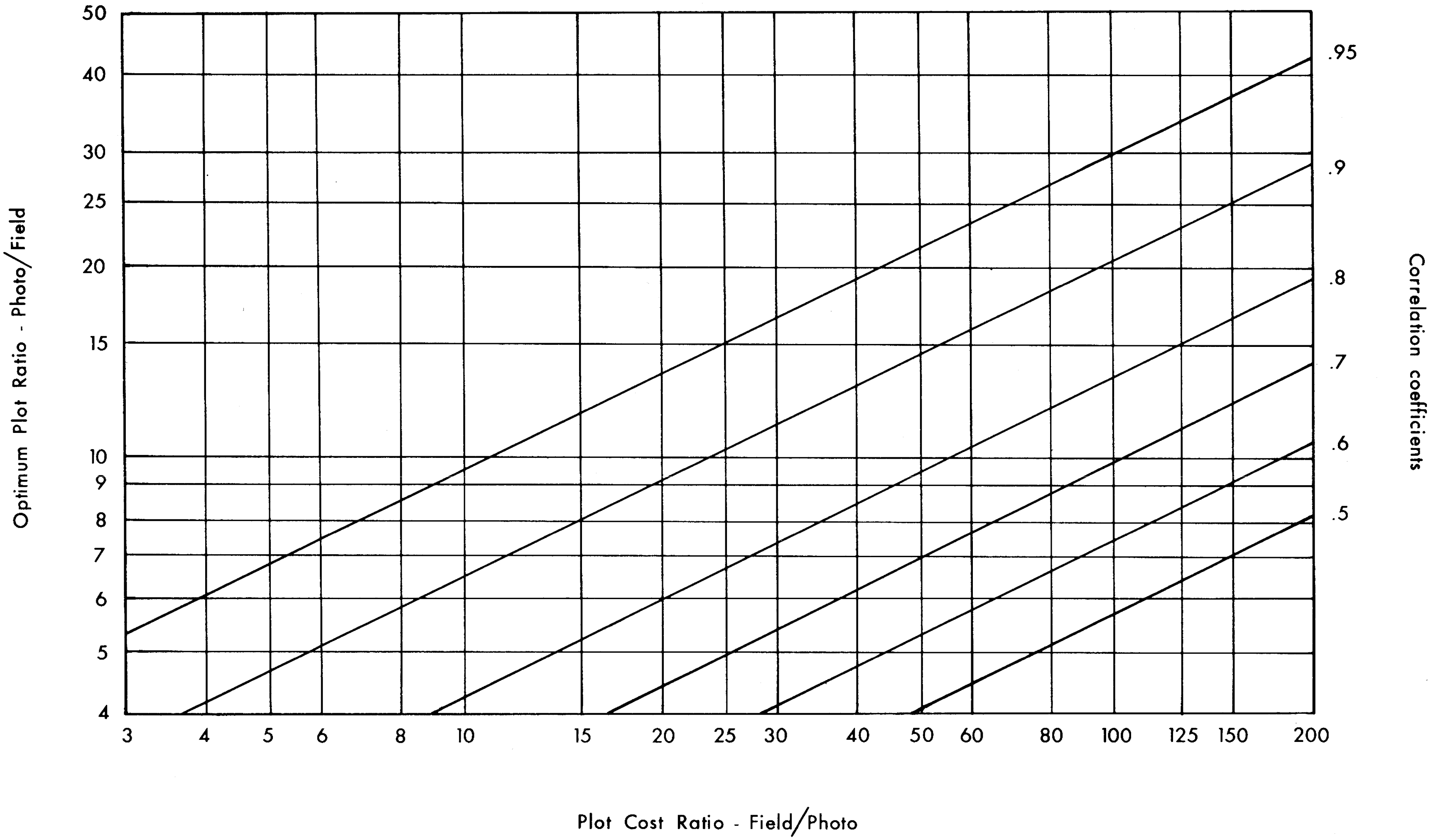
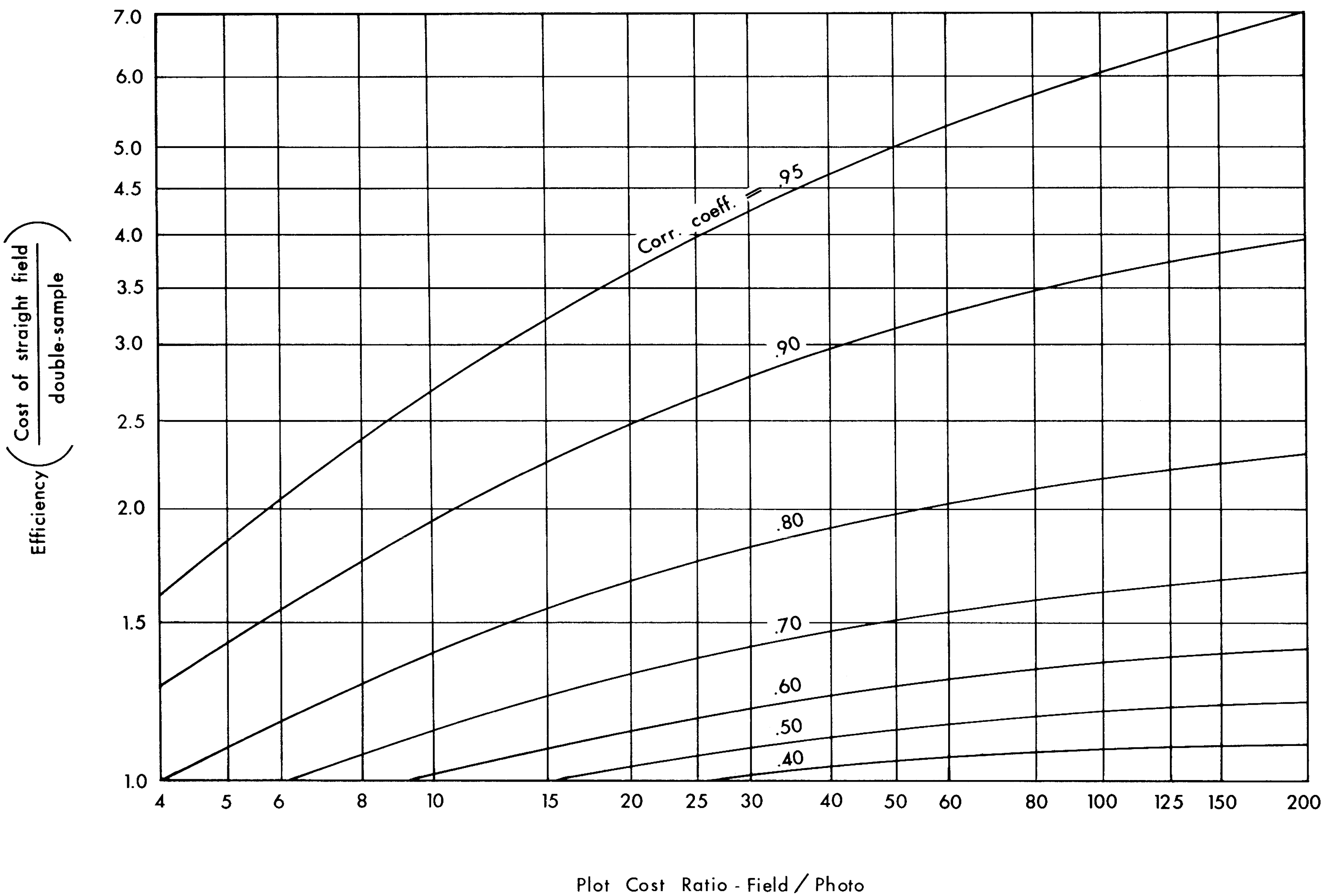


Figure 6

Efficiency of Double Sampling with Regression Using Photo Volume Estimates



SEASONAL IDENTIFICATION OF WESTERN PINE BEETLE LOSSES IN PONDEROSA PINE IN OREGON

	Previous Year		Current Year	
	Summer Brood	Winter Brood	Summer Brood	Winter Brood
Time of Attack	Early in spring to late in summer	Late in summer until cold weather	Early spring to late summer	Late summer until cold weather
Foliage	Dark red. Many of long needles fallen. Short needles still on ends of twigs.	Sorrel to red. Needles normal length. Some fallen	Green fading to sorrel. No loss of needles. New growth short on ends of twigs.	Fresh green to straw yellow. Fully developed needles.
Bark	Usually dry and loose with loose boring dust under bark. Pitch tubes hard and yellow. Many D.b. emergence holes. A number of large oval holes. No fresh woodpecker work. Old work, may consist of light to moderate scaling considerably weathered. Also many small round woodpecker holes through bark. Frequently many hard, dry fungus fruiting bodies, considerable portion of which have broken open or fallen.	Usually loose. Boring dust generally loose. White dust common in crevices. Pitch tubes becoming hard & yellow. Many D.b. emergence holes in bark. Some large, oval holes. Heavy woodpecker work frequent. None recent. Fungus fruiting bodies dry and hard, few in number.	Fairly loose and moist. Red and occasionally white boring dust in crevices. Pitch tubes red and becoming hard. May or may not be numbers of D.b. emergence holes. No large oval holes. Woodpecker work light to moderate. Frequently only small round holes through bark. Fungus fruiting bodies may be infrequent.	Moist and generally tight Red dust in crevices. Pitch tubes soft and red. Insect holes few. No large oval holes. Woodpecker work becoming prevalent. No fungus fruiting bodies.

SEASONAL IDENTIFICATION OF WESTERN PINE BEETLE LOSSES IN PONDEROSA PINE IN OREGON (cont'd).

	Previous Year		Current Year	
	Summer Brood	Winter Brood	Summer Brood	Winter Brood
Wood	Usually dry and checked. Much bluestain. Occasionally punky. Frequently many worm holes in sapwood.	Mostly dry, occasionally moist. Much bluestain. A few small worm holes.	Moist with considerable bluestain. May be a few small worm holes.	Moist, unstained to slightly bluestained. No worm holes.
Insects	Only a few secondary insects.	No D.b. many secondaries. An occasional roundheaded borer larva.	On trees attacked early in season emergence of D.b. brood complete, later trees may have larvae, pupae, and new adults. Many secondary insects both in adult and larval forms. Roundhead borers may range from small to full grown larvae.	D.B. new attacks, parent adults, eggs or larvae. On advanced trees may be a few small to half grown roundheaded borer larvae. May be clerid adults on bark. Few secondary insects under bark.